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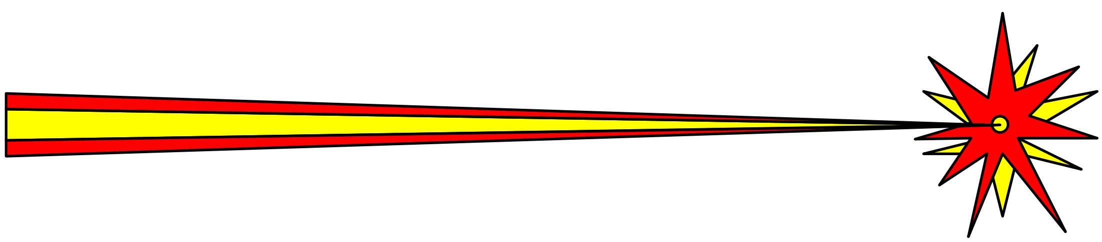
Langley Research Center

NONIONIZING RADIATION



National Aeronautics and Space Administration

Responsible Office: Safety and Mission Assurance Office

PREFACE

These procedural requirements, a part of the Langley Research Center (LaRC) Safety Manual, prescribe applicable nonionizing radiation standards by assigning responsibilities and authorities at this Center.

The standards and regulations contained herein do not in any way relieve supervisors, employees or contractors of their responsibilities for the conduct of safe operations.

LAPG 1710.8, dated July 1999, is rescinded and should be destroyed.

Delma C. Freeman, Jr.
Deputy Director

DISTRIBUTION:
SDL 040, SDL 043, SDL 410, SDL 411, and SDL 412
(LaRC Safety Manual Holders)
429/Safety and Facility Assurance Branch, SMAO (200 copies)

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AUTHORITY

American National Standard for the Safe Use of Lasers (ANSI Z136.1-1993).
American National Standard National Electric Code, ANSI/NFPA No. 70 1981, Articles 300 and 400.
American National Standard Safety Standard for Radio Receivers, Audio Systems and Accessories, ANSI/UL 127-1978.
Occupational Safety and Health Administration 29 Code of Federal Regulations 1910.97.

The below documentation is available from the Radiation Safety Officer.

CODE OF FEDERAL REGULATIONS (CFR):

Title 21	Food and Drugs Part 1040.10 - Laser Products
Title 29	Occupational Safety and Health Administration Part 1910.97 - Nonionizing Radiation

INDUSTRY STANDARDS:
American National Standard for the Safe Use of Lasers (ANSI Z136.1 1993), American National Standards Institute, Inc., 1430 Broadway, New York, New York.

Occupational Exposure to Ultraviolet Radiation, U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, 1972.

Threshold Limit Values (TLV) and Biological Exposure Indices, American Conference of Governmental Industrial Hygienists (1992 93) Edition.

Laser Safety Reference Book, Laser Institute of America, 4100 Executive Park Drive, Cincinnati, Ohio.

REFERENCES

LAPD 1150.2, "Boards, Panels, Committees, Councils and Teams."
LAPD 1700.1, “Safety Program."
LPR 1740.6, “Personnel Safety Certification.”
NASA Langley Form 44A, “Radiation Hazard Form.”
NASA Langley Form 49, “Safety Permit Request Laser/Microwave.”
NASA Langley Form 66, “Worker Appointment and Certification Form.”
NASA Langley Form 492, “Radiation Worker’s Certification Card.”
NASA Langley Form 498, “Safety Permit.”

Chapter 1

1. INTRODUCTION

1.1 PURPOSE

These procedural requirements describe the policy, organization, procedures, and requirements for the radiological health and safety activity of the Langley Research Center (LaRC), as they specifically pertain to nonionizing radiation activities at LaRC.

It is LaRC policy to comply with NASA regulations and Federal Laws as prescribed in Appendices A and B of these procedural requirements and to:

- exercise centralized control over operations involving use of hazardous radiation producing equipment.
- assure a safe level of exposure of personnel to nonionizing radiation from such equipment.
- assure compliance with applicable Federal, state, and local regulations.

A Nonionizing Radiation Committee (NIRC) is established under the authority of Langley Policy Directive (LAPD) 1700.1, “Safety Program,” and LAPD 1150.2, "Boards, Panels, Committees, Councils and Teams." The committee responsibilities are presented in Chapter 2 of this LPR.

1.2 SCOPE

These procedural requirements define requirements for the procurement, use, and handling of sources of nonionizing radiation. They also indicate sources from which more detailed information on nonionizing radiation may be obtained when necessary.

1.3 APPLICABILITY

The procedures and radiation protection practices as set forth in these procedural requirements apply to all organizational elements of LaRC and to all personnel working in or visiting areas under the administrative control of LaRC. Although intended primarily to apply to the use of lasers or laser systems, these procedures and practices may also apply to hazardous noncoherent sources of nonionizing radiation such as radars, solar simulators, and high-intensity arc lamps. Questions concerning details of current practices and procedures or their applicability shall be referred to the LaRC Radiation Safety Officer (RSO), (Health Physicist, Safety and Facility Assurance Branch (SFAB), Safety and Mission Assurance Office (SMAO).

It is the responsibility of contractors to provide and implement their own nonionizing radiation program. As a minimum, this program shall be in accordance with the LaRC program as described herein.

1.4 ISSUANCE AND CONTROL

SFAB is responsible for the issuance, distribution, and control of these procedural requirements. Revisions to these procedural requirements shall be developed by the LaRC NIRC in accordance with LAPD 1150.2. Specific changes shall be numbered and transmitted by the Safety Manager.

1.5 DEFINITIONS AND TERMINOLOGY

Appendices C, “Definitions and Terminology” and G, “Acronyms,” are included to assist the reader with these procedural requirements.

1.6 RECORDS

The following forms were completed when implementing requirements:

Records of all receipts and shipments of nonionizing radiation sources.
Records of the radiation surveys.
Records of the off-site radiation operations.
Records of trained and safety certified laser operators and radiation workers.
Medical surveillance (if required).
NASA Langley Form 44A, “Radiation Hazard Form.”
NASA Langley Form 49, “Safety Permit Request Laser/Microwave.”
NASA Langley Form 66, “Worker Appointment and Certification Form.”
NASA Langley Form 492, “Radiation Worker’s Certification Card.”
NASA Langley Form 498, “Safety Permit.”

Chapter 2

2. NONIONIZING RADIATION COMMITTEE (NIRC)

2.1 COMMITTEE AUTHORITY

Any member of the NIRC is authorized to investigate any questionable radiation source, equipment, system, procedure, and so forth; to act in the name of the LaRC Director to stop work; to prevent the use of equipment/procedure which is considered unsafe; and, to start action to eliminate the unsafe condition. This action shall be documented within 24 hours by formal letter to the Chairperson, NIRC. However, if line management is not in agreement with the corrective action recommended by the official who stopped the work, the line manager is to submit the reasons to the Chairperson, Executive Safety Board, who shall make an appropriate review. In these cases work shall not resume without the approval of the Chairperson, Executive Safety Board.

Due to the need for the NIRC to maintain an overview of nonionizing radiation activities at LaRC, a safety permit review system is established for major radiation facilities. This review system is described in Chapter 4, “Routine Procedures and Requirements.”

2.2 STRUCTURE AND ORGANIZATION

The NIRC functions as a committee of the Executive Safety Board. Its position in the organization for radiation safety is shown in Figure 2.1, LaRC Organization for Radiation Safety.

Committee members (including Chairperson and Vice Chairperson) are appointed by the Vice-Chairperson, Executive Safety Board, by virtue of their technical and/or educational expertise in the field of nonionizing radiation. A typical committee will consist of a Chairperson, Vice Chairperson, Secretary, and eleven additional qualified members. Members serve for a three-year term with the exception of the Safety Manager and the RSO who serve as long as the committee continues to function.

During the first meeting of each calendar year, the committee shall elect a committee secretary from its full membership. The committee secretary shall be responsible for preparing and distributing committee minutes in addition to other specified responsibilities.

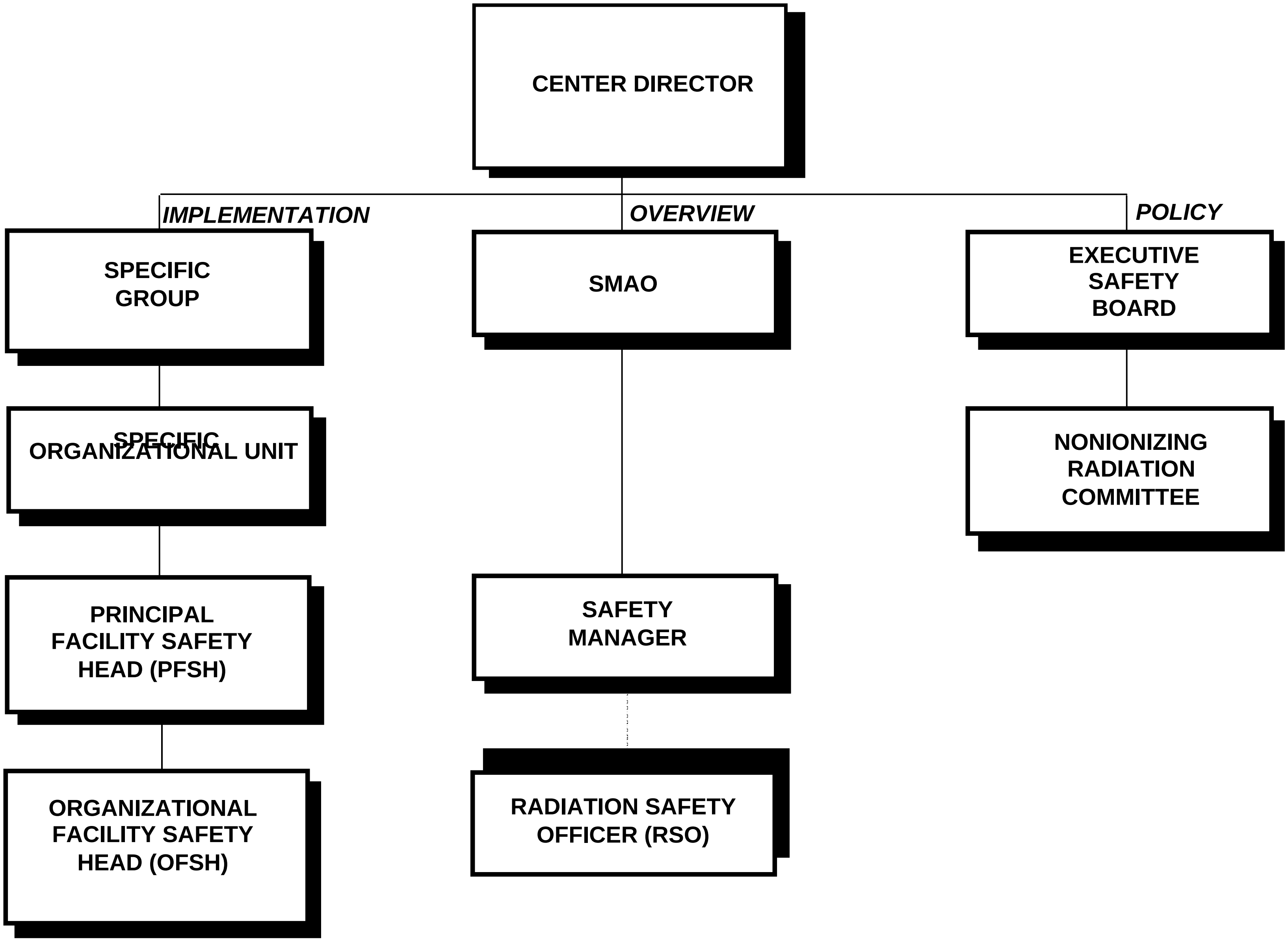

Figure 2.1, LaRC Organization for Nonionizing Radiation Safety

2.3 DUTIES AND RESPONSIBILITIES

2.3.1 General

To prevent unnecessary nonionizing radiation exposure to LaRC personnel and the surrounding populace, the NIRC shall exercise centralized control over sources of nonionizing radiation at LaRC. This control shall be accomplished by a review and approval of all procurement, handling, and use of sources of hazardous nonionizing radiation. In addition, the NIRC shall ensure that an audit is made of each facility's possession and use of sources of nonionizing radiation no less than annually (Chapter 5).

The NIRC is responsible for developing and coordinating material incorporated in these procedural requirements as the need arises.

2.3.2 Specific Duties and Responsibilities

2.3.2.1 Chairperson

The duties of the committee Chairperson are to:

- prepare agenda and call meetings as required but, at least quarterly.
- act as the presiding officer at committee meetings.
- act as the signature authority for actions approved by the committee.
- be cognizant of all matters pertaining to nonionizing radiation at LaRC.

2.3.2.2 Vice Chairperson

The duties of the committee Vice Chairperson are to:

- assist the Chairperson whenever necessary.
- serve as the Chairperson when the Chairperson is absent.

2.3.2.3 Secretary

The duties of the committee Secretary are to:

- prepare and distribute minutes of committee meetings which shall contain, as a minimum, a record of persons present and a description of matters discussed and conclusions reached, including the opinions of dissenting members, and copies of all reports issued or approved by the committee.
- distribute minutes to all members; Organizational Facility Safety Heads (OFSH's) concerned with nonionizing radiation; the Chairperson, Executive Safety Board; and the Director, SMAO.
- process official correspondence for the committee as needed.

2.3.2.4 Members

Member duties and responsibilities are to:

- be cognizant of all matters pertaining to nonionizing radiation safety at LaRC. This is chiefly, but not entirely, achieved by attending the committee meetings and participating in the decisions made by the committee.
- serve on ad hoc committees, appointed by the Chairperson, when necessary.

Chapter 3

3. SAFETY AND HEALTH FUNCTIONS

3.1 GENERAL

The responsibility for implementing the policies of these procedural requirements is divided among five safety and health functions. The interface requirements of these functions and their duties and responsibilities are presented in this Chapter.

3.2 ORGANIZATIONAL FACILITY SAFETY HEAD (OFSH)

The Principal Facility Safety Head (PFSH) of each facility where nonionizing radiation operations are performed shall appoint an OFSH for each operation, which is functionally or generically distinct. The OFSH shall, in each case, be a representative of line management who is thoroughly familiar with the nonionizing radiation operation and its hazards. In some cases, the OFSH may also be the prime user of the source(s) of nonionizing radiation.

3.2.1 Interfaces

The OFSH is the first point of contact for the individual who has a requirement for the procurement, use, or disposal of sources of nonionizing radiation. The first point of contact for the OFSH is the RSO.

3.2.2 Responsibilities

Responsibilities of the OFSH of an operation involving sources of nonionizing radiation are:

- supervise and coordinate, in a safe manner, the procurement, use, and disposal of sources of nonionizing radiation.
- maintain a running inventory of all nonionizing radiation sources used in operations. The inventory shall include locations of use, type of radiation emitted, and maximum radiation intensities produced by these sources.
- maintain a current list of employees in the operation who are required to be certified as radiation workers. Chapter 5, “Special Procedures and Requirements” presents the certification requirements.
- accompany the RSO during audits of the operation and, when appropriate, attend meetings of the NIRC.

3.3 RADIATION SAFETY OFFICER (RSO)

The position of the RSO has been designated within a contractor team of full time professional health physicists. The RSO is located in SFAB.

3.3.1 Interfaces

The RSO is responsible for reporting nonionizing radiation information to SMAO and the Safety Manager. The RSO is a member of the NIRC. Recommendations to the committee for approval or disapproval of new uses of nonionizing radiation are made by the RSO following pre-operational surveys and review of safety procedures. The RSO assists the radiation user as primary contact on a day-to-day basis for matters relating to radiation safety other than procurement.

3.3.2 Responsibilities

In general, the RSO provides administrative and technical guidance to LaRC personnel in the safe use of nonionizing radiation. The RSO shall:

- Prepare incident and overexposure reports required by the Occupational Safety and Health Administration (OSHA).
- Perform pre-operational surveys and radiation hazard analyses of all proposed uses of facilities for nonionizing radiation to assure conformity with applicable standards and good practice. Recommend to the NIRC approval or disapproval of these facilities.
- Perform annual audits of nonionizing radiation activity in each facility.
- Perform periodic radiation protection surveys and radiation safety evaluations as an integral part of the audit function.
- Assist line management in implementing radiation safety rules and procedures as promulgated by the NIRC.
- Provide training and indoctrination of personnel in radiation safety.
- Review all purchase requests for nonionizing radiation sources for compatibility with approved policies and safety programs.
- Inspect and maintain records of all receipts and shipments of nonionizing radiation sources.
- Periodically inform the NIRC of new developments in the field of nonionizing radiation, as they are applicable to activities at LaRC.

3.4 SAFETY MANAGER

The Head, SFAB, SMAO, is the Safety Manager.

3.4.1 Interfaces

The Safety Manager interfaces include:

- technically managing contractual health physics services at LaRC.
- serving as a member of the NIRC (or assign a designee).
- acting as the primary contact for LaRC management on matters relating to radiation safety.
- representing the government as the liaison between the RSO and federal regulatory authorities (OSHA, Food and Drug Administration [FDA], Federal Aviation Administration [FAA], etc.).

3.4.2 Responsibilities

The Safety Manager shall:

- exercise general surveillance over all uses of nonionizing radiation at LaRC, including on-site contractor activities to assure radiation use is in conformity with safe practice, pertinent regulations, and with provisions approved by the NIRC for specific radiation use authorizations (that is, safety permits).
- choose to have the RSO perform the above function.
- serve as the final reviewing and/or certifying authority on the following documents:
  - NASA Langley Form 66, “Worker Appointment and Certification Form.”
  - NASA Langley Form 44A, “Radiation Hazard Form.”
  - NASA Langley Form 498, “Safety Permit.”
  - NASA Langley Form 49, “Safety Permit Request Laser/Microwave.”
  - NASA Langley Form 492, “Radiation Worker’s Certification Card.”

3.5 OCCUPATIONAL HEALTH OFFICER (OHO)

The LaRC Occupational Health Officer (OHO) is a member of the Office of Human Resources (OHR).

3.5.1 Interfaces

The OHO’s interfaces include:

- Contracting Officer’s Technical Representative (COTR) for medical support services at LaRC (specifically, the LaRC Occupational Medical Center (OMC), 10 West Taylor Street, Facility 1149).
- Center’s prime contact for matters relating to occupational illnesses or injuries.

3.5.2 Responsibilities

The OHO’s responsibilities are to:

- determine adequacy of physical examination requirements for nonionizing radiation workers at LaRC and review new developments in the area of medical surveillance for these workers.
- review the medical disqualification of any LaRC employee as a nonionizing radiation worker with the contract ophthalmologist and the LaRC Medical Director.
- serve as a qualifying official for nonionizing radiation worker appointment and certification on NASA Langley Form 66.

3.6 RADIATION WORKERS

The OFSH having direct involvement with sources of nonionizing radiation shall forward recommendations for appointment of radiation workers and operators as described in Chapter 4, “Routine Procedures and Requirements.” Radiation operators are the only persons permitted to operate class 3b and class 4 lasers.

3.6.1 Interfaces

Radiation workers shall work under the direct authority of the OFSH.

3.6.2 Responsibilities

Radiation workers shall be:

- cognizant of and comply with the LaRC regulations pertaining to nonionizing radiation safety.
- fully aware of the limitations given in the Description of Duties block on the appointment form, and notify the OFSH when:
  - a change in the definition of the limitations is needed.
  - the need to work in restricted areas has ended.

3.7 LASER OPERATOR

The laser operator shall:

- prevent unauthorized personnel from entering a controlled area during hazardous operations.
- be responsible for the overall safety of all personnel in the laser work area.
- limit access to the laser work area to all personnel not necessary for the laser research operations (Chapter 5).
- exercise authority over the safe operation of the device to which the radiation operator is assigned.

Chapter 4

4. ROUTINE PROCEDURES AND REQUIREMENTS

4.1 GENERAL

Clearly defined procedures and requirements are a prerequisite for the orderly processing of documents and materials for any type of organizational structure. Procedures and requirements relating to nonionizing radiation at LaRC are included in this Chapter. Questions concerning procedures and requirements shall be directed to the RSO.

4.2 PROCUREMENT AND/OR RECEIPT

Prior to the procurement and receipt of any hazardous source of nonionizing radiation, the intended user or operator of the source shall complete NASA Langley Form 44A, "Radiation Hazard Form," and route the form to the RSO as the final repository. Where an OFSH has not been appointed, the intended user submits NASA Langley Form 44A to the PFSH. The PFSH shall then appoint an OFSH for the organization, which is procuring the source of nonionizing radiation.

Sources, which specifically require NASA Langley Form 44A, are:

- all class 3A, 3B, and 4 lasers and laser systems
  NOTE: These are the only lasers and laser systems that requires NASA Langley Form 44A. Laser pointers and CD rom drives are not regulated and do not require a Langley Form 44A.
- radio frequency (RF) generators capable of propagating RF power into free space in excess of 10 milliwatts per square centimeter for any 0.1-hour period.
- ultraviolet light sources as determined by the RSO.

4.2.1 Organizational Facility Safety Head (OFSH)

The OFSH is required to:

- review and approve NASA Langley Form 44A for systems safety compatibility and/or compatibility with research objectives.
- forward approved NASA Langley Form 44A to the RSO.

4.2.2 Radiation Safety Officer (RSO)

The RSO is responsible for:

- scheduling a pre-operational survey with the OFSH upon receipt of NASA Langley Form 44A. The purpose of this survey is to provide the OFSH with guidance and assistance in the following areas:
  - applicability of safety permit requirements.
  - preparation of safety procedures.

  - preparation of authorizing documents specified in this Chapter.
- signing NASA Langley Form 44A following the survey and forwarding it to the Safety Manager.

4.2.3 Safety Manager

The Safety Manager's responsibilities include:

- On receipt of NASA Langley Form 44A, review the RSO's survey and approve or disapprove the purchase of the nonionizing radiation source.
- If disapproved, return NASA Langley Form 44A to the OFSH with a written explanation of disapproval attached. The OFSH may appeal disapprovals, through the OFSH's Organizational Unit Manager, to the Executive Safety Board.
- If approved, sign NASA Langley Form 44A, detach Copy 2, and forward as appropriate.

4.2.4 Purchasing Officer, Office of Procurement

After receipt of an approved NASA Langley Form 44A, complete the information indicated in the upper right-hand corner of the form. If a contract is let for purchase of the material, detach Copy 3 of NASA Langley Form 44A and forward Copy 4 to the Logistics Management Team (LMT).

4.2.5 Receiving (LMT)

Upon receipt of any incoming source of nonionizing radiation authorized by NASA Langley Form 44A, immediately notify the RSO of its arrival at LaRC. A copy of the receiving document shall be furnished to the RSO.

4.3 AUTHORIZATION OF USE (NASA LANGLEY FORM 498, "SAFETY PERMIT")

Some sources of nonionizing radiation require the completion of a NASA Langley Form 49, "Safety Permit Request - Laser/Microwave" and subsequent approval and issuance of a NASA Langley Form 498, "Safety Permit" before the source can be used or operated at any LaRC facility. (Appendix C, "Suggested Outline for NASA Langley Form 49, "Safety Permit Request - Laser/Microwave Preparation") The RSO is responsible for the determination of NASA Langley Form 498 requirements during the processing of NASA Langley Form 44A (Chapter 5).

As a general rule, the following sources of nonionizing radiation shall require the issuance of NASA Langley Form 498:

- class 3b lasers or laser systems, the use of which creates a significant possibility that its users or operators will be exposed to radiation levels in excess of the applicable maximum permissible exposure (MPE) (Chapters 5, "Special Procedures and Requirements").
- all class 4 lasers or laser systems.
- all radio frequency (RF) generators capable of propagating RF power into occupied areas in excess of those limits, which allow a whole body specific absorption rate of 0.4 w/kg in any 0.1-hour for a specific wavelength.

- ultraviolet light sources, as determined by the RSO, the use of which creates a significant probability that its users or operators will be exposed to ultraviolet radiation levels in excess of applicable MPE as recommended by the National Institute for Occupational Safety and Health (NIOSH). (Appendix A, "Exposure Standard for Nonlaser Ultraviolet Radiation," presents the determination of the MPE for nonlaser ultraviolet radiation.)
- magnetic field sources, as determined by the RSO, the use of which creates a significant probability that its users or operators will be exposed to magnetic flux densities in excess of the applicable threshold limit values (TLV's) as recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). The determination of the TLV for magnetic flux densities is presented in Appendix D.
- static electric field sources, as determined by the RSO, with whose proposed use there exists a significant probability that its users or operators will be exposed to electric flux densities in excess of the applicable TLV's as recommended by ACGIH. The determination of the TLV for magnetic flux densities is presented in Appendix D.

The NASA Langley Form 498 is a formal written designation that the particular research experiment, rig, or operation has been reviewed by technically qualified members of the LaRC staff and that all reasonable safety precautions and environmental requirements have been considered and subsequently implemented. The NASA Langley Form 49 shall describe the maximum potentially hazardous operating parameters (that is, maximum radiant power, radiant energy, kilovoltage, amperage, and so forth) expected during the life of the experiment or operation. Changes in the operational configuration which, (1) do not exceed the authorized maximum parameters, or (2) change the authorized safety features, will not require the processing of a modified NASA Langley Form 498. Other changes require additional review and approval by the NIRC. NASA Langley Form 498 is valid for a period of one year from date of issuance for new facilities; and thereafter, for a period of four years.

4.3.1 Organizational Facility Safety Head (OFSH)

The OFSH shall:

- prepare NASA Langley Form 49, and attach pertinent drawings, sketches, and supporting information (Appendix C, "Suggested Outline for NASA Langley Form 49, "Safety Permit Request - Laser/Microwave" Preparation.")
- verify that a Worker Appointment and Certification Form (NASA Langley Form 66 for NASA employees) or its equivalent (for contractor employees) has been submitted for each radiation worker listed as a user/operator.
- forward NASA Langley Form 49 and attachments to the RSO.
- post the approved NASA Langley Form 498 (and a copy of NASA Langley Form 49) in a conspicuous place at the specified site or if more practical, in the applicable control center for the site.
- submit a NASA Langley Form 49 for renewal to the Safety Manager at least 30 days prior to its expiration date or submit a new NASA Langley Form 49 through

channels anytime a change is required in the authorized maximum operating parameters.

4.3.1.1 Radiation Safety Officer (RSO)

The RSO shall:

- perform a radiation hazard analysis of the proposed operation upon receipt of NASA Langley Form 49 and attachments.
- work closely with the OFSH during this analysis to provide guidance and assistance in the preparation and acquisition of safety procedures, protective equipment, and medical surveillance (if required).
- forward NASA Langley Form 49, attachments, and the hazard analysis (with appropriate recommendations) to the NIRC for their review and action.
- verify certification listings of radiation workers and laser operators.

4.3.1.2 Nonionizing Radiation Committee

The NIRC shall:

- review NASA Langley Form 49 to determine that all reasonable precautions have been taken and whether the proposed operations can be carried out with an acceptable level of risk to personnel and equipment. Based on this review the NIRC shall:
  - approve issuance of NASA Langley Form 498 with conditions, if any.
  - disapprove the NASA Langley Form 49 and return to the OFSH if problem areas are evident.
  - withhold approval or disapproval until additional information is obtained. The OFSH shall be notified of this action.
- review existing NASA Langley Form 498 as part of the annual audit to ensure that they are valid (either not expired or have been reviewed before expiration date).

4.3.1.3 Committee Chairperson

The NIRC Chairperson shall:

- complete NASA Langley Form 49 and specify, when appropriate, any special conditions on which approval is based.
- forward the approved NASA Langley Form 49 and attachments to the Safety Manager, Mail Stop 429.

4.3.1.4 Safety Manager

The Safety Manager shall review NASA Langley Form 49 for impact on the environment or creation of safety hazards outside the scope of radiological health. Based on this review the Safety Manager will:

- sign NASA Langley Form 498 and return all attached documentation to the OFSH.
- return NASA Langley Form 49 and all attached documentation to the OFSH if problem areas are evident.

4.4 USE OF LASERS IN NAVIGABLE AIRSPACE (CLASSES 3A, 3B, OR 4)

The Federal Aviation Administration (FAA) is responsible for regulating the safe and efficient utilization of navigable air space and ensuring the safety of aircraft. Laser experiments or programs that will involve the use of laser or laser systems (other than Classes 1 or 2) in navigable airspace shall be coordinated with the FAA (Washington, DC 20590, or any FAA regional office) in the planning stages to ensure control of any attendant hazard to airborne personnel and equipment.

Chapter 5

5. SPECIAL PROCEDURES AND REQUIREMENTS

5.1 SPECIAL REQUIREMENTS FOR OFF-SITE RADIATION USE AUTHORIZATION

Additional requirement and approvals are needed for LaRC organizations wishing to operate lasers and/or other nonionizing radiation sources off-site. The term off-site refers to any facility not under the administrative control of LaRC, such as another NASA facility, a contractor's site, open-air operations, or air and space flights. In these circumstances, the following requirements shall be satisfied in addition to the NASA Langley Form 498:

- An OFSH from the requesting organization, having primary responsibility for all safety aspects associated with the operation of such system shall be appointed for the off-site operation. The OFSH shall be the point of contact for any issues or concerns the NIRC might have regarding the use of the source or sources for the off-site operations.
- Major and/or long-term projects shall be required to include a safety review as part of the total design review process. The OFSH is responsible for notifying the NIRC of any design review meetings.
- Written authorization shall be obtained from the administration or authorities for the jurisdiction or site in which the nonionizing radiation source is to be operated. Use of the nonionizing radiation source shall be concurred by the safety organization for that jurisdiction.
- To assure minimal radiation exposure to individuals, the OFSH with the cognizance or guidance of the RSO shall perform monitoring tasks as determined necessary by the NIRC.
- All records of the radiation surveys shall be maintained by the OFSH and submitted to the RSO at the completion of the authorized use. Any incident involving overexposure to individuals shall be reported immediately to the RSO and the NIRC Chairperson.

The NIRC shall:

- Assign a committee member to act as liaison for each organization operating off-site experiments. This committee member shall work closely with the OFSH to ensure that all nonionizing safety issues associated with the experiment are addressed and that the required NASA Langley Form 49's are submitted.
- Assign to the Vice-Chairperson of the committee the lead responsibility to ensure that all off-site operations meet all requirements prior to deployment of said operation.

The RSO, in support of off-site operations, shall:

- act as the initial point of contact between the NIRC and the organization and/or individual wishing to operate a nonionizing radiation source off site.
- maintain records of the off-site operations such as NASA Langley Form 498's, approval correspondence, safety violations or incidents, and other pertinent documentation.
- relay any reported incident or violation to SMAO, the Executive Safety Board, and the NIRC.
- assist with safety calculations.

5.1.1 Failure to Comply

Failure to comply with this or any other regulation in LPR 1710.8, may result in the suspension or termination of the nonionizing radiation safety permit.

5.2 INTERIM APPROVALS

When an immediate use of nonionizing radiation is determined necessary, the RSO, with verbal concurrence from the Chairperson, NIRC may temporarily modify the following previously approved authorizations to:

- extend an expiration date of a NASA Langley Form 498 for a period not to exceed 60 days.
- add specific users to NASA Langley Form 498 provided they have met the standards of training and experience established by the NIRC.
- add to the sources of nonionizing radiation named on an approved authorization.
- authorize a new use location and/or procedure provided the new location and/or procedure is equipped with safety features (interlocks, warning signs, area control, and so forth) which meet or exceed those authorized under the existing NASA Langley Form 498.

The NIRC shall evaluate these temporary modifications, and if satisfied that the RSO's action was proper, ratify the actions at the next committee meeting. However, approvals may be withdrawn at any time if safety violations occur or use of a source is found not to be in compliance with conditions of the approved authorization.

5.3 AUDITS

The RSO is responsible for conducting an audit of each facility possessing sources of nonionizing radiation no less frequent than annually. The annual audit is comprised of four quarterly segments. Approximately one fourth of this Center's activity involving nonionizing radiation shall be audited each quarter and the results of the audit presented to the NIRC during their quarterly meetings.

OFSH’s shall be notified by letter one week in advance of the exact day(s) their audit will be conducted. Typical items covered during an audit are:

- inventories of:
  - lasers and laser systems.
  - RF sources/microwave sources.
  - ultraviolet sources.
  - magnetic sources.
  - electric sources.
- records of:
  - trained and safety certified laser operators and radiation workers.
  - medical surveillance (if required).
- compliance with terms of NASA Langley Form 498.
- conduct of routine radiation protection surveys by the RSO.

5.4 TRAINING AND CERTIFICATION

All personnel who operate, manipulate, or who have any other type of physical control over the use of radiation-producing equipment or material specifically authorized by a NASA Langley Form 498 (new or existing) are required to be trained and safety certified as radiation workers in accordance with LPR 1740.6, “Personnel Safety Certification.” It is the responsibility of each OFSH to ensure that personnel within the facility are trained and certified. Questions concerning this requirement should be directed to the RSO.

5.4.1 Qualifications

As a minimum, and prior to working with nonionizing radiation, individuals shall have had experience and/or training on specific topics. NASA Langley Form 66, is used to determine and certify qualifications for worker training and safety certification described above and in accordance with LPR 1740.6. Contractor personnel shall use a form, which supplies the equivalent information contained in NASA Langley Form 66. Worker recertification is accomplished by a yearly laser course.

5.4.2 Safety Permits

NASA Langley Form 66 for individuals working on a new or existing operation or experiment involving nonionizing radiation shall be processed as an attachment to NASA Langley Form 49 (Chapter 4, “Routine Procedures and Requirements”). NASA Langley Form 66 is processed by the RSO to add individuals as authorized users to an existing NASA Langley Form 498 as described in this Chapter.

5.4.3 Certification Card

Based on the satisfactory completion of NASA Langley Form 66 and/or qualifying status of the worker, the RSO shall issue, revalidate (yearly), or terminate a NASA Langley Form 492, "Radiation Worker Certification Card. The NASA Langley Form 492 shall be identified with the number of the NASA Langley Form 498(s) with which the work is associated. The worker shall have the card on-hand or readily accessible, as proof of his/her certification, while performing applicable tasks.

5.5 MEDICAL SURVEILLANCE

Personnel requiring certification as nonionizing radiation workers shall be given a complete initial and termination eye examination by the Center's contract ophthalmologist prior to being issued and on termination of a NASA Langley Form 492 in accordance with LPR 1740.6. These examinations are normally accomplished through routine processing of NASA Langley Form 66 and in accordance with established LaRC Occupational Medicine Examination Protocol. The RSO is responsible for the notification of the eye examinations through the auspices of the LaRC OHO. A medical disqualification of any LaRC employee as a nonionizing radiation worker shall be the result of a decision made by the ophthalmologist in consultation with the LaRC OHO and the LaRC Medical Director.

5.6 RECEIPT

LMT shall notify the RSO of all arrivals of sources of nonionizing radiation authorized by NASA Langley Form 44A. Such notification shall be given within 24 hours following arrival of the source at LaRC.

5.7 INTERNAL TRANSFER

All sources of nonionizing radiation authorized by a NASA Langley Form 498 and located in a particular facility shall not be transferred to the accountability of another organization, or transferred from one location to another within LaRC, without prior notification of the RSO and subsequent modification of the existing NASA Langley Form 498, as described in this chapter. This requirement is in addition to any action required for NASA property control procedures.

5.8 LASER HAZARD CLASSIFICATION

The laser classification scheme is based on the knowledge that any laser or laser system shall be classified according to its accessible radiation during operation. Classification labeling which is used in conformance with the Federal Laser Product Performance Standard shall be used to satisfy this labeling requirement. Should it be necessary in the event that a laser or laser system has been modified subsequent to classification by the manufacturer, the RSO shall classify the laser or laser system following the criteria provided in the American National Standard for the Safe Use of Lasers (ANSI Z136.1-1993).

5.8.1 Class 1 or Exempt Lasers

Class 1 or Exempt lasers cannot emit a hazardous level of laser radiation. These include any laser, or laser system containing such a laser, that cannot emit accessible laser radiation levels in excess of the class 1 accessible emission limit (AEL) for the maximum possible duration inherent in the design of the laser or laser system.

5.8.2 Class 2 or "Low-Power" Laser Devices

Class 2 or “Low Power” laser devices are visible lasers which do not have enough power to injure a person, but which may produce retinal injury when viewed directly for more than 0.25 second. These lasers include:

- visible (0.4 - 0.7 µm) continuous wavelength (cw) lasers or laser systems which can emit accessible radiant power exceeding the class 1 AEL for the maximum possible duration inherent in the design of the laser or laser system (0.4 µW for emission duration greater than 3 x 10^4 second), but not exceeding one mW.
- visible (0.4 - 0.7 µm) repetitively pulsed lasers or laser systems which can emit accessible radiant power exceeding the class 1 AEL for the maximum possible duration inherent in the design of the laser or laser system, but not exceeding the class 1 AEL 0.25 second exposure.
- visible (0.4 - 0.7 µm) lasers and laser systems intended for a specific use where the input is not intended to be viewed shall be designated class 2a by the RSO, provided that the accessible radiation does not exceed the class 1 AEL for an exposure duration less than or equal to 10^3 second.

5.8.3 Class 3 Medium Power Lasers and Laser Systems

Class 3 lasers are subclassified as either class 3a or class 3b. Class 3a includes only visible lasers that cannot induce eye injury when viewed intrabeam with the unaided eye, but may cause retinal damage if the energy is collected and focused into the eye with converging lens such as binoculars or microscopes. Class 3a lasers are defined as those lasers having an accessible output power between one and five times the lowest appropriate class 3 limit (see above) and which do not exceed the appropriate Maximum Permissible Exposure (MPE) as measured over the limiting aperture.

All other lasers in class 3 are subclass 3b. Class 3b consists of lasers, which can produce incidental injury if viewed directly. Intrabeam viewing of either the direct or a mirror like (specular) reflection of the beam should also be considered hazardous. These lasers include:

- infrared (1.4 µm - 1 mm) and ultraviolet (0.2 - 0.4 µm) lasers and laser systems which can emit accessible radiant power in excess of the class 1 AEL for the maximum possible duration inherent in the design of the laser or laser system, but cannot emit an average radiant power in excess of 0.5 W for exposure of 0.125 J within an exposure time less than 0.25 second.
- visible (0.4 - 0.7 µm) continuous-wave (cw) or repetitively pulsed lasers or laser systems producing accessible radiant power in excess of the class 1 AEL for an 0.25 second exposure (1 mW for a cw laser), but which cannot emit an average radiant power greater than 0.5 W.
- visible and near infrared (0.4 - 1.4 µm) single pulsed lasers which can emit accessible radiant energy in excess of the class 1 AEL, but which cannot emit a radiant exposure that exceeds 0.125 J or that required to produce a hazardous diffuse reflection. American National Standards Institute (ANSI) Z136.1 1993 or the RSO may be consulted to determine maximum radiant exposures needed to produce hazardous reflections from diffuse surfaces.
- near infrared (0.7 - 1.4 µm) cw lasers or single repetitively pulsed lasers which can emit accessible radiant power in excess of the class 1 AEL for the maximum duration inherent in the design of the laser or laser system, but cannot emit an average power of 0.5 W or greater for periods in excess of 0.25 second.

5.8.4 Class 4 Lasers

Lasers, which not only produce a hazardous direct or specularly reflected beam but also a hazardous diffuse reflection and a significant skin hazard. These lasers include:

- ultraviolet (0.2 - 0.4 µm) and infrared (1.4 µm - 1 mm) lasers and laser systems which emit: (1) an average accessible radiant power in excess of 0.5 W for periods greater than 0.25 second; or (2) a radiant exposure of 0.125 J within an exposure duration of 0.25 second or less.
- visible (0.4 - 0.7 µm) and near infrared (0.7 - 1.4 µm) lasers and laser systems which emit: (1) an average accessible radiant power of 0.5 W or greater for periods greater than 0.25 second; or (2) a radiant exposure in excess of 0.03 CaJ, or that required to produce a hazardous diffuse reflection.

NOTE: Summaries of laser and laser system classifications have been derived as indicated in Tables 5.1, Typical Laser Classification --- Continuous-Wave (CW) Lasers and 5.2, Typical Laser Classifications --- Single-Pulse Lasers. The RSO may be consulted for additional details.

5.9 CONTROL MEASURES AND PROCEDURES FOR LASER CLASSIFICATIONS

Appropriate control measures and procedures shall be used for all lasers and laser systems at LaRC to reduce the possibility of exposure of the eye and skin to hazardous laser radiation, and to other hazards associated with operation of laser devices. For all lasers and laser systems, it is mandatory that the minimum radiation level be used for the required application.

Table 5.1, Typical Laser Classification - Continuous-Wave (CW) Lasers

Wavelength (μm)	Laser Type	Wavelength (μm)	Class 1* (W)	Class 2 (W)	Class 3b (W)	Class 4 (W)
Ultraviolet 0.180 to 0.280	Neodymium:YAG (Quadrupled) Argon	0.266 only 0.275	$\leq 9.6 \times 10^{-9}$ for 8 hours	-----	> Class 1 but $\leq$ 0.5	> 0.5
Ultraviolet 0315 to 0.400	Helium-Cadmium Argon Krypton	0.325 only 0.351, 0.363 only 0.3507, 0.3564 only	$\leq 3.2 \times 10^{-6}$	-----	> Class 1 but $\leq$ 0.5	> 0.5
Visible 0.400 to 0.700	Helium-Cadmium Argon (Visible) Krypton Neodymium:YAG (Doubled) Helium-Neon Dye Helium-Selenium	0.4416 only 0.457, 0.476, 0.488, 0.514, etc. 0.530 0.532 0.543 0.400 - 0.550 0.460 - 0.550	$\leq 0.4 \times 10^{-6}$	> Class 1 but $\leq 1 \times 10^{-3}$	> Class 1 but $\leq$ 0.5	> 0.5
	Helium-Neon Dye InGaAlP Ti:Sapphire Krypton	0,632 0.550 - 0.700 0.670 0.670 0.6471, 0.6764	$\leq 7 \times 10^{-6}$ $\leq 0.4 \times 10^{-6} - 7 \times 10^{-5}$ $\leq 2.4 \times 10^{-5}$ $\leq 2.4 \times 10^{-5}$ $\leq 1.1 \times 10^{-5}, 3 \times 10^{-5}$			
Near Infrared 0.700 to 1.400	GaAlAs GaAlAs GaAs Neodymium:YAG Helium-Neon InGaAsP	0.780 0.850 0.905 1.064 1.080, 1.152 only 1.310	$\leq 0.18 \times 10^{-3}$ $\leq 0.25 \times 10^{-3}$ $\leq 0.32 \times 10^{-3}$ $\leq 0.64 \times 10^{-3}$ $\leq 0.64 \times 10^{-3}$ $\leq 4.40 \times 10^{-3}$	-----	> Class 1 but $\leq$ 0.5	> 0.5
Far Infrared 1.400 to 10^3	InGaAsP Holmium Erbium Hydrogen Fluoride Helium-Neon Carbon Monoxide Carbon Dioxide	1.550 2.100 2.940 2.600 - 3.000 3.390 only 5.000 - 5.500 10.6	$\leq 9.6 \times 10^{-3}$	-----	> Class 1 but $\leq$ 0.5	> 0.5
	Water Vapor Hydrogen Cyanide	118 337	$\leq 9.5 \times 10^{-2}$			

*Assumes no mechanical or electrical design incorporated into laser system to prevent exposures from lasting to T_{max} = 8 hours (one workday); otherwise the Class 1 AEL could be larger than tabulated.

Table 5.2, Typical Laser Classification - Single-Pulse Lasers						
Wavelength (μm)	Laser Type	Wavelength (μm)	Pulse Duration (s)	Class 1 (J)	Class 3b (J)	Class 4 (J)
Ultraviolet 0.180 to 0.400	Excimer (ArF)	0.193	2×10^{-8}	$\leq 1.9 \times 10^{-6}$ *	> Class 1 but < 0.125	> 0.125
	Excimer (KrF)	0.248	2×10^{-8}	$\leq 1.9 \times 10^{-6}$ *	> Class 1 but < 0.125	> 0.125
	Neodymium: YAG Q-sw (Quadrupled)	0.266	2×10^{-8}(Q-sw)	$\leq 1.9 \times 10^{-6}$ *	> Class 1 but < 0.125	> 0.125
	Excimer (XeCl)	0.308	2×10^{-8}	$\leq 4.3 \times 10^{-6}$ *	> Class 1 but < 0.125	> 0.125
	Nitrogen	0.337	1×10^{-8}	$\leq 3.6 \times 10^{-6}$ *	> Class 1 but < 0.125	> 0.125
	Excimer (XeF)	0.351	2×10^{-8}	$\leq 4.3 \times 10^{-6}$ *	> Class 1 but < 0.125	> 0.125
Visible 0.400 to 0.700	Rhodamine 6G (Dye Laser)	0.450-0.650	1×10^{-6}	$\leq 0.2 \times 10^{-6}$	> Class 1 but ≤ 0.03	> 0.03
	Copper Vapor	0.510, 0.578	2.5×10^{-8}	$\leq 2 \times 10^{-6}$	n/a	n/a
	Neodymium: YAG (Doubled)	0.532	20×10^{-9} (Q-sw)	$\leq 0.2 \times 10^{-6}$	> Class 1 but ≤ 0.03	> 0.03
	Ruby	0.6943				
	Ruby (Long Pulse)	0.6943	1×10^{-3}	$\leq 4 \times 10^{-6}$	> Class 1 but ≤ 0.03	> 0.03
Near Infrared 0.700 to 1.4	Ti:Sapphire	0.700-1.000	6×10^{-6}	$\leq 1.9\text{-}7.7 \times 10^{-7}$	> Class 1 but ≤ 0.03	> 0.03
	Alexandrite	0.720-0.800	1×10^{-4}	$\leq 0.76\text{-}1.1 \times 10^{-6}$	> Class 1 but ≤ 0.03	> 0.03
	Neodymium: YAG	1.064	20×10^{-9} (Q-sw)	$\leq 2 \times 10^{-6}$	> Class 1 but ≤ 0.15	> 0.15
Far Infrared 1.4 to 10^3	Erbium: Glass	1.540	10×10^{-9} (Q-sw)	$\leq 9.7 \times 10^{-2}$	> Class 1 but ≤ 0.125	> 0.125
	Co:Magnesium-Fluoride	1.750-2.500	8×10^{-5}	$\leq 9.7\text{-}9.7 \times 10^{-3}$	n/a	> 0.125
	Holmium	2.100	2.5×10^{-4}	$\leq 9.7 \times 10^{-3}$	n/a	> 0.125
	Hydrogen Fluoride	2.600-3.000	4×10^{-7}	$\leq 1.1 - 0.11 \times 10^{-3}$	n/a	> 0.125
	Erbium	2.940	2.5×10^{-4}	$\leq 6.8 \times 10^{-3}$	n/a	> 0.125
	Carbon Dioxide	10.6	1×10^{-7} (Q-sw)	$\leq 9.7 \times 10^{-4}$	> Class 1 but ≤ 0.125	> 0.125
	Carbon Dioxide	10.6	1×10^{-3}	$\leq 9.6 \times 10^{-3}$	n/a	> 0.125

* Assuming that both eye and skin may be exposed, i.e., 1.0 mm beam (area of limiting aperture = 7.9×10^{-3} cm^2).

The following control measures and procedures were derived from the American National Standard for the Safe Use of Lasers (ANSI Z136.1 1993): Laser Classifications 1, 2, 2a, and 3a.

5.9.1 Laser Classifications 1, 2, 2a, and 3a

The only control measure applicable to these lasers shall be an appropriate warning label affixed to a conspicuous place on the laser housing or control panel or both the housing and control panel (Labeling and Area Posting Requirements are described in this chapter, for label required).

The labeling requirement specified above shall also be the only control measure applicable to those class 3b lasers with whose use the RSO has determined that there is little probability of eye exposure in excess of the applicable MPE (those not requiring a Safety Permit).

5.9.2 Laser Classification 3b

Those class 3b lasers which have been determined to require the issuance of an approved NASA Langley Form 498 for their use shall comply with the following control measures and procedures. Exceptions to this requirement shall have the prior written approval of the NIRC before NASA Langley Form 498 can be issued.

5.9.2.1 Education and Training

All persons using the laser or laser system shall be informed about the potential hazards of laser operations.

5.9.2.2 Engineering Controls

Priority shall be given to the incorporation of appropriate safety mechanisms as an integral part of the laser or laser system. Examples include beam stops, beam enlarging systems, enclosures, shutters, interlocks, and so forth.

5.9.2.3 Laser Controlled Area

Consideration shall be given to operation of laser devices in a controlled area. Special emphasis shall be placed on control of the path of the laser beam.

5.9.2.4 Laser Operators

Only certified personnel, who possess a laser certification, NASA Langley Form 492, issued by the RSO shall operate the laser.

5.9.2.5 Spectators

Spectators shall not be permitted into the laser-controlled area unless appropriate supervisory approval has been obtained and protective measures taken.

5.9.2.6 Beam Enclosures

The emitted laser radiation shall be contained within enclosures whenever practicable. Laser beams emitted by non-enclosed systems shall be terminated at the end of the useful beam path when the exposure level is greater than the MPE for direct irradiation of the eye and a possibility of human exposure exists.

5.9.2.7 Alignment Procedures

Alignment of laser optical systems (mirrors, lenses, beam deflectors, and so forth) shall be performed in such a manner that the primary beam, or a specular reflection of the primary beam, does not expose the eye to a level above the MPE for direct irradiation of the eye.

5.9.2.8 Optical Viewing Aids

Optical systems such as lenses, telescopes, microscopes, and so forth, may increase the hazard to the eye when viewing a laser beam; therefore, special care shall be taken in their use. Microscopes and telescopes may be used as optical instruments for viewing, but shall be provided with an interlock or filter, if necessary, to prevent ocular exposures above the appropriate MPE for irradiation of the eye.

5.9.2.9 Eye Protection

Eye protection devices, which are specifically designed, for protection against radiation from the laser system shall be used when engineering and procedural controls are inadequate to eliminate potential exposure in excess of the applicable MPE. For cases in which long term exposure to the eye by visible lasers (only) is not intended, the applicable MPE may be based on a 0.25-second exposure.

5.9.2.10 Equipment Labeling

Lasers shall have warning labels with the appropriate cautionary statement affixed to a conspicuous place on the laser housing or control panel, or on both the housing and control panel.

5.9.2.11 Diffusely Reflecting Materials

In addition to beam stops, shields, and enclosures, materials which will diffusely reflect any stray or incidental laser beams shall be used in laser areas whenever possible.

5.9.3 Laser Classification 4

The probability of injury and the extent of injury increases with increasing laser output power. High-power lasers require more rigid control measures, not only because there is a greater likelihood that specular reflections will have sufficient power to cause injury, but because of the greater risk of injury from hazardous diffuse reflections. The entire beam path capable of producing hazardous diffuse reflections shall be controlled. Controls shall rely primarily on more positive methods, such as enclosures and interlocks, and secondarily upon procedural safeguards.

Therefore, **in addition** to the control measure specified for class 3b lasers described above, the following controls shall apply to all class 4 laser systems at LaRC:

5.9.3.1 Laser Controlled Area

Specific laser controlled area requirements shall include:

- Laser devices shall be isolated in an area designated for laser operations. Access to such an area shall require appropriate authorization.
- Under conditions where the entire beam path is not enclosed, safety latches or interlocks shall be used to prevent unauthorized entry into laser controlled areas. Such measures shall be designed to allow both rapid egress by laser personnel at all times and admittance to the laser controlled area in an emergency condition. For such emergency conditions, a “panic button” (control disconnect switch or equivalent device) shall be available for deactivating the laser. Interlock overrides are permissible in laser controlled areas with specific approval by the RSO.
- During tests requiring continuous operation, the person in charge of the controlled area shall be permitted to momentarily override the safety interlocks to allow access of other authorized personnel if it is clearly evident that there is no radiation hazard at the point of entry, and if the necessary protective devices are worn by the entering personnel.
- Should removal of the protective covers or the overriding interlocks become necessary for special training, service adjustments, or maintenance procedures, a temporary laser controlled area shall be devised following specific procedures approved by the RSO which will outline all safety requirements during the service and maintenance procedures. Such a temporary laser controlled area shall nevertheless provide for all safety requirements for all personnel, both within and without the temporary laser controlled area during the service or maintenance procedure.
- Under conditions where the entire beam path is not completely enclosed and the laser is capable of emission, access to the laser-controlled area shall be limited to persons wearing laser protective eyewear. In this case, all other optical paths (for example, windows) from the facility shall be covered or restricted in such a way as to reduce the transmitted intensity of the laser radiation to levels at or below the MPE for direct irradiation of the eye. Specularly reflecting surfaces, which are not required when using the laser, shall be removed from the beam path.
- The purpose of control measures is to reduce the possibility of exposure to hazardous levels of laser radiation and to associated hazards. Therefore, it may not be necessary to implement all of the control measures given. Whenever the application of any one or more control measures reduces the possible exposure to a level at or below the applicable MPE, the application of additional control measures should not be necessary.

5.9.3.2 Enclosed Beam Path

Whenever possible, the entire beam path, including the interaction area, that is, the area in which irradiation of materials by the primary or secondary beams occurs, shall be enclosed. Enclosures shall be equipped with interlocks so that the laser system will not operate unless such enclosures are installed. For pulsed systems, interlocks shall be designed so as to prevent firing of the laser, by dumping the stored energy into a dummy load. For cw lasers, the interlocks shall turn off the power supply or interrupt the beam by means of shutters. Interlocks shall not allow automatic re-energizing of the power supply, but shall be designed so that after tripping the interlock, the power supply or shutter shall be reset manually.

5.9.3.3 Eye Protection

Eye protection devices (described in this chapter) which are designed for protection against radiation from a specific laser system shall be used when engineering and procedural controls are inadequate to eliminate potential exposure in excess of the applicable MPE. For cases in which long term exposures to the eye by visible lasers (only) are not intended, the applicable MPE may be based on a 0.25-second exposure.

5.9.3.4 Remote Firing and Monitoring

Whenever possible, the laser system shall be fired and monitored from remote positions.

5.9.3.5 Warning Systems

Warning systems are required for lasers as follows:

- An alarm system, for example, an audible sound, or a warning light visible through protective eyewear, or a verbal “countdown” command, shall be used prior to laser activation.
- The audible system may consist of a bell or chime which commences when a pulsed laser power supply is charged for operation, for example, during the charging of capacitor banks. Systems shall be used in which a warning will sound intermittently during the charging procedure (pulsed systems) and continuously when fully charged.

5.9.3.6 Key-Switch Master Interlock

Any laser or laser system designated as class 4 shall be provided with an operative keyed master interlock or switching device. The key shall be removable and the device shall not be operable when the key is removed.

5.9.4 Special Controls for Invisible Laser Radiation

Since infrared and ultraviolet radiation are invisible, special care shall be taken when using laser system emitting radiation in the infrared and ultraviolet spectrums. Thus, in addition to the control measures which apply to the laser hazard classifications for class 3b and class 4, requirements in the following paragraphs shall also apply.

5.9.4.1 Infrared Lasers

Infrared lasers beam path termination and control are required as follows:

- The beam from a class 3b infrared laser or laser system shall be terminated by a highly absorbent backstop wherever practicable. **NOTE:** Many surfaces which appear “dull” visually can act as reflectors of infrared radiation.

- The beam from a class 4 laser or laser system shall be terminated in a fire resistant material wherever practicable. Periodic inspection of the absorbent material is required since many materials degrade with use.
- Areas, which are exposed to reflections from class 3b infrared lasers or laser systems, shall be protected by appropriately blocking the beam or target area with infrared absorbent material.
- In the case of beams from class 4 lasers or laser systems, the screening material shall be fire resistant.

5.9.4.2 Ultraviolet Lasers

Exposure to ultraviolet radiation shall be minimized by using beam shields of material, which attenuates the radiation to levels below the MPE for the specific ultraviolet wavelength.

Special attention shall be given to the possibility of producing undesirable reactions in the presence of ultraviolet radiation, for example, formation of skin sensitizing agents, ozone, and so forth.

5.9.5 Control of Laser Explosion Hazards

High-pressure arc lamps and filament lamps in laser equipment shall be enclosed in housings, which can withstand the maximum explosive pressures resulting from lamp disintegration. The laser target and elements of the optical train which may shatter during laser operation shall also be enclosed or equivalently protected to prevent injury to operators and observers.

5.9.6 Control of Laser Electrical Hazards

The intended application of the laser equipment determines the method of electrical installation and connection to the power supply circuit (for example, conduit versus flexible cord). All equipment shall be installed as outlined in American National Standard National Electric Code, ANSI/NFPA No. 70 1981(as updated), or the most current issue, Articles 300 and 400. (Such installed equipment is acceptable to the U. S. Department of Labor, OSHA, if accepted, certified, listed, labeled, or otherwise determined safe by a qualified testing laboratory, such as, but not limited to, Underwriters Laboratories [UL] Incorporated, and Factory Mutual Corporation.)

5.9.6.1 Shock Hazard

Controls as follows are required to avoid laser electrical shock hazards:

- Live parts of circuits and components with peak open circuit potentials over 42.5 volts are considered hazardous, unless limited to less than 0.5 mA. Such circuits require positive protection against contact. For equipment intended for general use, interlock switches (and capacitor bleeder resistors if applicable) or their equivalent shall be installed to remove the voltage from accessible live parts to permit servicing operation. Bleeder resistors shall be of such size and rating as to carry the capacitor discharge current without burnout or mechanical injury. Circuits and components with peak open-circuit potentials of 2500 volts or more shall be adequately covered or enclosed if an appreciable capacitance is associated with the circuits.
- If servicing of equipment requires entrance into an interlocked enclosure, a solid metal grounding rod shall be utilized to assure discharge of high voltage capacitors. The grounding rod shall be firmly attached to ground prior to contact with the potentially live point. A resistor grounding rod (for example, a large wattage ceramic resistor) may be used prior to application of the aforementioned solid conductor grounding rod to protect circuit components from overly rapid discharge, but not as a replacement.

5.9.6.2 Grounding

The frames, enclosures, and other accessible metal noncurrent carrying metallic parts of laser equipment shall be grounded. Grounding shall be accomplished by providing a reliable, continuous, metallic connection between the part or parts to be grounded and the grounding conductor of the power wiring system.

5.9.6.3 Electrical Fire Hazards

Components in electrical circuits shall be evaluated with respect to fire hazards. Circuit components of combustible material, such as transformers, that do not pass a short-circuit test without ignition (American National Standard Safety Standard for Radio Receivers, Audio Systems and Accessories, ANSI/UL 127-1978 or the most current issue) shall be provided with individual noncombustible enclosures. Power supply circuit wiring shall be completely enclosed in noncombustible material.

5.9.6.4 Electrical Hazards from Explosion

Gas laser tubes and flash lamps shall be supported to ensure that their terminals cannot make any contact which will result in a shock or fire hazard in the event of a tube or lamp failure. Components such as electrolytic capacitors may explode if subjected to voltages higher than their ratings, with the result that ejected metal may bridge live electrical parts. Such capacitors should be tested to make certain that they can withstand the highest probable potentials should other circuit components fail, unless the capacitors are adequately contained so as not to create a hazard.

5.10 LABELING AND AREA POSTING REQUIREMENTS

Labeling and area posting is required for nonionizing radiation.

5.10.1 Lasers

The following laser labeling and area posting are required:

- No labeling or area posting is required for class 1 lasers or laser systems.
- Class 2, class 2a, and class 3a lasers or laser systems shall have appropriate warning labels affixed to the laser housing or control panel or on both the housing and control panel. These labels are available from the RSO. No area posting is required for class 2 and class 3a lasers.
- Class 3b and class 4 lasers or laser systems shall have appropriate warning labels affixed to the laser housing or control panel or on both the housing and control panel. In addition, all entrances to a “laser controlled area” (see control requirements above) shall be posted with an appropriate warning sign. These labels and signs are available from the RSO.

5.10.2 Radio-Frequency Sources (RF)

Those stationary RF sources determined to require an approved NASA Langley Form 498 for their use are subject to the posting requirements of the OSHA Occupational Safety and Health Standards (29 Code of Federal Regulations (CFR) 1910.97). Copies of this standard are available from the RSO.

5.10.3 High Intensity Arc Lamps or Solar Simulators

All high intensity arc lamps, solar simulators, or other light sources capable of producing hazardous levels of ultraviolet radiation shall have their source housings labeled and each access to the immediate work area posted with the following warning statement:

This requirement is not applicable to those sources, which are enclosed, or when

CAUTION **HIGH INTENSITY ULTRAVIOLET ENERGY** **PROTECT EYES AND SKIN**

operating procedures specify the work area is to be evacuated before the source is energized.

5.11 MAXIMUM PERMISSIBLE EXPOSURE (MPE) TO LASER RADIATION

Much research has been conducted in recent years to evaluate the specific hazards associated with direct (intrabeam) and indirect (reflected) exposure to laser radiation. Present experience, however, indicates that the accuracy of these evaluations is almost always limited by biological uncertainties. Until these uncertainties are resolved, one is obliged to use significant safety factors based upon knowledge of the accuracy of the experimental data, the problems of extrapolating from animal to human, variation of susceptibility among individuals, and the experience gained from accidental injuries. For these reasons, MPE values are below known hazardous levels. Compliance with control procedures required by these procedural requirements assure personnel will not be exposed to laser radiation in excess of MPE values.

Since MPE values are a function of source geometry (either intrabeam or extended source conditions), wavelength, exposure duration, and critical organ (eye or skin), no simplified table of MPE values exists for all types of lasers. ANSI Z136.1 1993 or the RSO should be consulted for details.

5.12 LASER PROTECTIVE EYEWEAR

Laser protective eyewear shall be worn when engineering and/or administrative controls are impractical or insufficient to reduce eye exposure to laser radiation below the applicable MPE. The OFSH shall be responsible for the determination and procurement of appropriate protective eyewear for each laser or laser system. The following factors shall be considered in determining the appropriate protective eyewear:

- wavelength of laser output.
- radiant exposure or irradiance.
- MPE value.
- optical density of eyewear at the specific laser output wavelength visible light transmission requirement.
- minimum radiant exposure or irradiance at which damage to the laser protective eyewear might be expected to occur.
- need for prescription glasses.
- comfort.
- degradation of absorbing media.
- need for peripheral vision.

If necessary, the RSO shall assist the OFSH in these determinations.

5.12.1 Specification of Optical Density, D_λ

The attenuation of Optical Density, D_λ, of laser protective eyewear at a specific wavelength shall be specified. Many lasers radiate at more than one wavelength; thus eyewear designed to have an adequate D_λ for a particular wavelength could have a completely inadequate D_λ at another wavelength radiated by the same laser. This problem may become particularly serious with lasers that are tunable over broad frequency bands.

If the Actual Eye Exposure is given by H_o, then the D_λ required of protective eyewear to reduce this exposure to the MPE is given by:

$$D_\lambda = \log_{10} (H_o / MPE)$$

where the units of H_o are the same as those of the appropriate MPE. It should be noted that optical densities greater than three or four (depending on exposure time) could reduce eye exposures below the ocular MPE but leave the unprotected skin surrounding the eyewear exposed to values in excess of the MPE for skin exposure. Attenuation through the protective material shall be determined from all anticipated viewing angles and at all wavelengths.

5.12.2 Visible Transmission

Adequate D_{λ}, at the laser wavelengths of interest, shall be weighed with the need for adequate visible transmission.

5.12.3 Identification of Eyewear

All laser protective eyewear shall be clearly labeled with optical density values and wavelengths for which protection is afforded.

5.12.4 Comfort and Fit

Protective eyewear shall provide a comfortable and snug fit so that laser radiation is satisfactorily attenuated before reaching the viewer's eyes.

5.12.5 Inspection

Periodic inspections shall be made by each user of protective eyewear to ensure the maintenance of satisfactory conditions, to include:

- inspecting the attenuator material for pitting, crazing, cracking, and so forth.
- inspecting the goggle frame for mechanical integrity and light leaks.
- ensuring that labeling of protective eyewear is in compliance with this Chapter.

LPR 1710.8 APPENDICES

A. EXPOSURE STANDARD FOR NONLASER ULTRAVIOLET RADIATION

(Reference: Reprinted from the National Institute for Occupational Safety and Health recommended standard for Occupational Exposure to Ultraviolet Radiation, 1972).

RECOMMENDATIONS FOR AN ULTRAVIOLET RADIATION STANDARD

- The National Institute for Occupational Safety and Health (NIOSH) recommends that occupational exposure to ultraviolet energy in the workplace be controlled by compliance with the “Exposure Standards” below. Ultraviolet radiation (ultraviolet energy) is defined as that portion of the electromagnetic spectrum described by wavelengths from 200 to 400 nm. (Additional definitions and conversion factors are available in the referenced document.) Adherence to the recommended standards will, it is believed, prevent occupational injury from ultraviolet radiation, that is, will prevent adverse acute and chronic cutaneous and ocular changes precipitated or aggravated by occupational exposure to ultraviolet radiation.
- Sufficient technology exists to prevent adverse effects on workers, but technology to measure ultraviolet energy for compliance with the recommended standard is inadequate, so work practices are recommended for control of exposure in cases where sufficient measurement or emission data are not available.
- These criteria and the recommended standard will be reviewed and revised when relevant information warrants.

EXPOSURE STANDARDS

- For the ultraviolet spectral region of 315 to 400 nm, total irradiance incident on unprotected skin or eyes, based on either measurement data or on output data, shall not exceed 1.0 mW/cm^2 for periods greater than 1000 seconds, and for exposure times of 1000 seconds or less, the total radiant energy shall not exceed 1000 $mW.sec/cm^2$ (1.0 J/cm^2).

- For the ultraviolet spectral region of 200 to 315 nm, total irradiance incident on unprotected skin or eyes, based on either measurement data or on output data, shall not exceed the levels described below. Measurement techniques are discussed in the referenced document.

- If the ultraviolet energy is from a narrow band or monochromatic source, permissible dose levels for a daily 8 hour period can be read directly from Figure B.1, or, for selected wavelengths, from Table B.1.

- If the ultraviolet energy is from a broad band source, the effective irradiance, I_{eff}, relative to a 270 nm monochromatic source shall be calculated from the formula below. From I_{eff}, the permissible exposure time in seconds for unprotected skin or eyes shall be computed by dividing 0.003 J/cm^2, the permissible dose of 270 nm radiation, by I_{eff} W/cm^2.

$$\mathbf{I_{eff} = \sum I_\lambda S_\lambda \Delta_\lambda}$$

where: I_{eff} = effective irradiance relative to a monochromatic source at 270 nm
I_λ = spectral irradiance in $W/cm^2/nm$
S_λ = relative spectral effectiveness (unitless); see Table B-1 for values of S_λ at different wavelengths
Δ_λ = bandwidth in nm

Table B-2 lists permissible exposure times corresponding to selected values of I_{eff} in $\mu W/cm^2$.

- If radiation intensity from a point source is known at some distance from the worker, for example, from measurement at another point or from output data at a known distance from the ultraviolet source, attenuation of radiation from that point to the worker can be calculated from the principle that radiation decreases with the square of the distance it must travel. For example, an object three feet away from a radiation source receives one-ninth the energy of an object one foot away. This assumption is conservative in some instances, since ultraviolet radiation, especially at very low wave-lengths, may be absorbed by some components of the atmosphere. Where information on atmospheric absorption of ultraviolet radiation is known, further correction may be applied. The calculation of intensity of radiation at any given point by use of the inverse square formula explained above does not take into consideration reflected energy.
- The recommended standard is not proposed for application as a standard to lasers. It should be recognized that significant non-occupational exposure to ultraviolet radiation can occur from exposure to sunlight, particularly during the summer months.

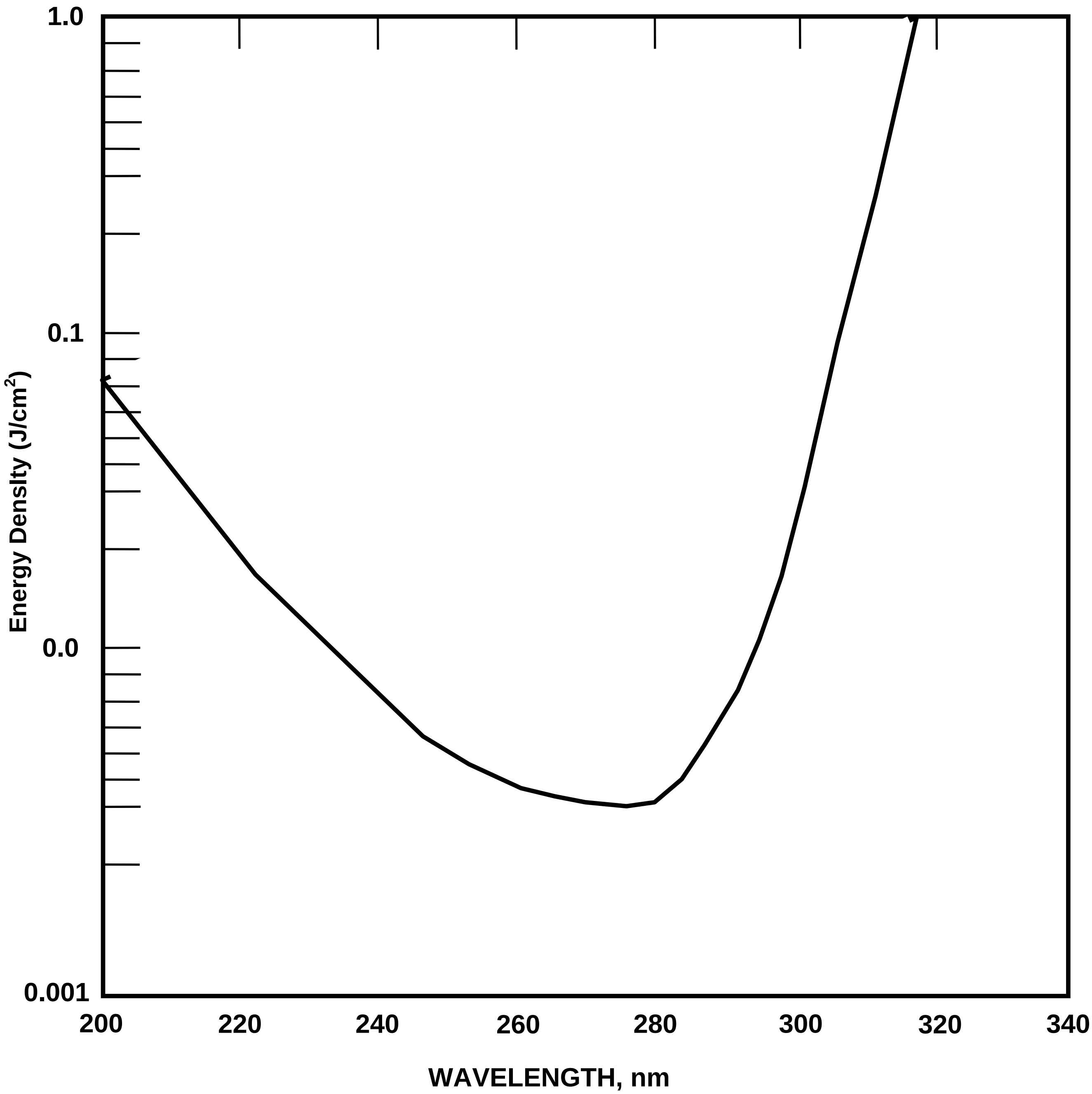

Figure B.1, Recommended Ultraviolet Radiation Exposure Standard.
NOTE: This figure was adapted from a figure developed and published by the American Conference of Governmental Industrial Hygienists in “Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1972.”

TABLE B.1, Total Permissible 8 Hour Doses and Relative Spectral Effectiveness of Some Selected Monochromatic Wavelengths.		
Wavelength (nm)	**Permissible 8-Hour Dose (mJ/cm^2)**	**Relative Spectral Effectiveness (S_λ)**
200	100.0	0.03
210	40.0	0.075
220	25.0	0.12
230	16.0	0.19
240	10.0	0.30
250	7.0	0.43
254	6.0	0.50
260	4.6	0.65
270	3.0	1.00
280	3.4	0.88
290	4.7	0.64
300	10.0	0.30
305	50.0	0.06
310	200.0	0.015
315	1000.0	0.003
This table was adapted from a table developed and published by the American Conference of Governmental Industrial Hygienists in "Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1972."		

TABLE B.2, Maximum Permissible Exposure Times for Selected Values of I_{eff}.	
Duration of Exposure Per Day	**Effective Irradiance I_{eff} ($\mu W/cm^2$)**
8 hr	0.1
4 hr	0.2
1 hr	0.8
30 min	1.7
15 min	3.3
10 min	5.0
5 min	10.0
1 min	50.0
30 s	100.0
This table was adapted from a table developed and published by the American Conference of Governmental Industrial Hygienists in "Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1972."	

B. DEFINITIONS AND TERMINOLOGY

absorption	Transformation of radiant energy to a different form of energy by interaction with matter.
accessible emission limits (AEL)	The maximum accessible level permitted within a particular class.
accessible radiation	If it is possible for the human eye or skin to be exposed to laser radiation in normal usage, then it is considered to be accessible.
actual eye exposure, H_o	Measured as irradiance (I).
amperes, A	Measurement of current.
α **min**	The limiting angular subtense.
aperture	An opening through which radiation can pass.
apparent visual angle	The angular subtense of the source as calculated from the source size and distance from the eye.
attenuation	The decrease in the radiant flux as it passes through an absorbing or scattering medium.
bandwidth, $\Delta\lambda$	Change in wavelength between different laser outputs.
beam diameter	The distance between diametrically opposed points in that cross section of a beam where the power per unit area is 1/e times that of the peak power per unit area.
beam divergency	The full angle of the beam spread between diametrically opposed 1/e irradiance points; usually measured in milliradians (1 milliradian = 3.4 minutes of arc).
beam expander	A combination of optical elements which will increase the diameter of a laser beam.
beam splitter	An optical device which uses controlled reflection to produce two beams from a single incident beam.
calorimeter	A device for measuring the total amount of energy absorbed from a source of electromagnetic radiation.

carcinogenic	Capable of causing cancer in a biological system.
coherent	A light beam is said to be coherent when the electric vector at any point in it is related to that at any other point by a definite, continuous sinusoidal function.
collimated beam	Effectively, a “parallel” beam of light with very low divergence or convergence.
collimator	An optical device for converting a diverging or converging beam of light into a collimated or “parallel” one.
continuous wave (cw)	The output of a laser which is operated in a continuous rather than pulsed mode. In this standard, a laser operating with a continuous output for a period greater than 0.25 second is regarded as a cw laser.
controlled area	An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from radiation hazards.
cornea	The transparent outer coat of the human eye which covers the iris and the crystalline lens. It is the main refracting element of the eye.
diffraction	Deviation of part of a beam, determined by the wave nature of radiation, and occurring when the radiation passes the edge of an opaque obstacle.
diffuse reflection	Change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.
diffusion	Change of the spatial distribution of a beam of radiation when it is deviated in many directions by a surface or by a medium.
DC	Direct current.
E	Electric field strength.
electric fields (static)	Electric fields propagated from an electrical source with frequencies at 30,000 Hertz and below.
electromagnetic	The flow of energy consisting of orthogonally vibrating

radiation	electric and magnetic fields lying transverse to the direction of propagation. X rays, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency and wavelengths.
energy, Q	The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers, and is generally expressed in joules.
exposure	The product of an irradiance and its duration.
extended source	An extended source of radiation can be resolved by the eye into a geometrical image, in contrast to a point source of radiation, which cannot be resolved into a geometrical image.
focal length	The distance from the secondary nodal point of a lens to the primary focal point. In a thin lens, the focal length is the distance between the lens and the focal point.
focal point	The point toward which radiation converges or from which radiation diverges or appears to diverge.
frequency, f	Speed of light (c) x wavelength. Number of wavelengths passing a set distance per unit time.
G, Gega	10^{12} .
hertz (Hz)	The unit which expresses the frequency of a periodic oscillation in cycles per second.
I_λ	Spectral Irradiance in $w/cm^2/nm$.
infrared radiation	Electromagnetic radiation with wavelengths which lie within the range 0.7 μm to 1 mm.
integrated radiance, L	The integral of the radiance over the exposure duration. Also known as pulsed radiance ($J.cm^{-2}.sr^{-1}$).
intrabeam viewing	The viewing condition whereby the eye is exposed to all or part of a laser beam.
irradiance (at a point of a surface), E	Quotient of the radiant flux incident on an element of the surface containing the point, by the area of that element. Unit: watt per square centimeter ($W.cm^{-2}$).

joule (J)	A unit of energy; 1 joule = 1 watt second.
laser	The device which produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels. Also, an acronym for "Light Amplification by Stimulated Emission of Radiation."
laser system	An assembly of electrical, mechanical, and optical components which includes a laser.
lasing medium	A material emitting coherent radiation by virtue of stimulated electronic or molecular transitions to lower energy levels.
limiting angular subtense (α min)	The apparent visual angle which divides intrabeam viewing from extended-source viewing.
limiting aperture	The maximum circular area over which radiance and radiant exposure can be averaged.
lossy medium	A medium which absorbs or scatters radiation passing through it.
M, Mega	10^6.
MPE	Maximum Permissible Exposure. The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the skin or eye.
magnetic flux density,B	Magnetic field strength per unit area.
magnetic field (static)	Magnetic fields propagated from a magnetic source with frequencies at 30,000 Hertz and below.
magnetic field strength, **H**	Strength of magnetic field in $w/m^{2.}$
maser (optical)	An older name for a laser, with microwave (of optical frequency) replacing light in laser.
meter (m)	A unit of length in the international systems of units; currently defined as a fixed number of wavelengths, in vacuum, of the orange red line of the spectrum of krypton 86. Typically, the meter is subdivided into the following units: Centimeter = 10^{-2} m (cm) Millimeter = 10^{-3} m (mm)

Micrometer = 10^{-6} m (µm)
Nanometer = 10^{-9} m (nm)

microwave radiation An electromagnetic wave having a wavelength of approximately 1 meter to 1 millimeter corresponding to frequencies of about 300 to 300,000 megacycles per second.

nominal ocular hazard distance (NOHD) The distance along the axis of the beam from the laser to the human eye beyond which the irradiance or radiant exposure is not expected to exceed the appropriate MPE.

optical density, D_λ Logarithm to the base ten of the reciprocal of the transmittance, D_λ = $-\log_{10\tau\lambda}$, where τ is transmittance.

optically pumped laser A laser in which the electrons are excited into an upper energy state by the absorption of light from an auxiliary light source.

point source A source of radiation whose dimensions are small enough compared with the distance between source and receptor for them to be neglected in calculations.

power The time rate at which energy is emitted, transferred, or received; usually expressed in watts (or in joules per second).

power density, PD Same as E, irradiance.

prf Abbreviation for pulse repetition frequency. High prf - more than 1 Hz.

root mean square, rms Square root of the arithmetic mean.

pulsed laser A laser which delivers its energy in the form of a single pulse or a train of pulses. In this standard, the duration of a pulse <0.25 s.

pulse duration The time duration of a laser pulse; usually measured as the time interval between the half power points on the leading and trailing edges of the pulse.

Q-switch A device for producing very short (≈30 ns), intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

Q-switched laser	A laser which emits short (≈30 ns), high-power pulses by utilizing a Q-switch.
radian	A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle: 1 radian, 57.3 degrees; 2π radians = 360 degrees.
radiance, L	Radiant flux or power output per unit solid angle per unit area ($W.sr^{-1}.cm^{-2}$).
radiant energy, Q	Energy emitted, transferred, or received in the form of radiation. Unit, joule (J).
radiant exposure, H	Surface density of the radiant energy received. Unit, joules per centimeter squared ($J.cm^{-2}$).
radiant flux (ϕ), radiant	Power emitted, transferred, or received in the form of power radiation. Unit: watt (W).
radiant intensity, I (of a source in a direction)	Quotient of the radiant flux leaving the source, (propagated in an element of solid angle containing the given direction, by the element of solid angle. Unit: watt per steradian ($W.sr^{-1}$).
reflectance, reflectivity	The ratio of total reflected radiant power to total incident power. Reflectivity may vary with several parameters such as wavelength.
reflection	Deviation of radiation following incidence on a surface.
repetitively pulsed laser	A laser with multiple pulses of radiant energy occurring in a sequence.
shall	The word “shall” is understood to mean mandatory.
should	The word “should” is understood to mean that which is advisory.
solid angle	The ratio of the area on the surface of a sphere to the square of the radius of that sphere. Unit: steradian (sr).
source	The term “source” is taken to mean either laser or laser illuminated reflecting surface.
specular reflection	A mirror like reflection.

spectral effectiveness	The ability to absorb light.
specific absorption rate, SAR	Rate at which the body absorbs heat at a specific frequency, based on a weighted TLV at a known wavelength (w/gram).
steradian (sr)	The unit of measure for a solid angle. There are 4π steradians in a sphere.
Tesla (T)	The unit of flux density given by the magnetic flux produced in an electromotive force of one volt as it is reduced to zero in a uniform rate in one second.
transmission	Passage of radiation through a medium.
transmittance	The ratio of total transmitted radiant power to total incident radiant power.
ultraviolet radiation	Electromagnetic radiation with wavelengths smaller than those for visible radiation. For the purposes of this standard, 0.2 - 0.4 μm.
visible radiation (light)	Electromagnetic radiation which can be detected by the human eye. It is commonly used to describe wavelengths which lie in the range between 0.4 μm and 0.7 μm.
volt, v	Current (A) x resistance (Ohm).
watt (W)	The unit of power, or radiant flux.
wavelength	The distance between two points in a periodic wave which has the same phase is called a wavelength.

C. SUGGESTED OUTLINE FOR NASA LANGLEY FORM 49, "SAFETY PERMIT REQUEST - LASER/MICROWAVE" PREPARATION

I. Brief description of activity objectives.

II. List of all laser operators and radiation workers to be in controlled area during hazardous source operation and their operational responsibilities (NASA Langley Form 66s for new personnel should be forwarded with NASA Langley Form 49 and currently qualified personnel listed in Item 6 of the form).

III. Planned schedule of operations and estimated frequency of operation.

IV. Safety operating plans:

  A. Operational area security and control
  B. Safety interlocks and overrides
  C. Weather restrictions (if outside)
  D. Any conditions that would preclude operations
  E. Assignments of operational personnel
  F. Operational countdown procedure or preparational steps
  G. Safety eyewear (wavelength, density)
  H. Order of action during laser operation
  I. MPE calculations (if necessary)
  J. Laser inventory if too numerous for cover sheet (include class, and so forth)

V. Sketches of operational area and actual experimental configuration (include map if outside)

Availability of Forms:

- NASA Langley Form 49, "Safety Permit Request -Laser/Microwave is available through the NASA Langley Management System.
- Worker Appointment and Certification Form (NASA Langley Form 66) and Radiation Hazard Form (NASA Langley Form 44A) are available from Stock.

D. EXPOSURE STANDARDS FOR RADIO FREQUENCY/MICROWAVE RADIATION

(Reference: Reprinted from the American Conference of Governmental Industrial Hygienists [1992 1993] Edition).

D.1 RECOMMENDATIONS FOR A MICROWAVE STANDARD

The ACGIH recommends that occupational exposure to microwave radiation in the workplace be controlled by compliance with the “Exposure Standards” described below. Microwave radiation (microwave energy) is defined as that portion of the electromagnetic spectrum described by wavelengths from one meter to one millimeter. These criteria and the recommended standard will be reviewed and revised when relevant information warrants.

Exposure Standards -- Radio Frequency/Microwave Radiation

These Threshold Limit Values (TLVs) refer to radio frequency (RF) and microwave radiation in the frequency range from 30 kHz to 300 GHz, and they represent conditions under which it is believed workers may be repeatedly exposed without adverse health effects. The TLVs shown in Table F.1 are selected to limit the average whole body specific absorption rate (SAR) to 0.4 W/kg in any 6 minute (0.1 hr) period for 3 MHz to 300 GHz (Figure F.1). Between 30 kHz and 3 MHz, the average whole body SAR is still limited to 0.4 W/kg, but the plateau at 100 mW/cm2 was set to protect against shock and burn hazards.

Since it is usually impractical to measure the SAR, the TLVs are expressed in units that are measurable, viz, squares of the electric and magnetic field strength, averaged over any 0.1 hour period. This can be expressed in units of equivalent plane wave power density for convenience. The electric field strength (E) squared, magnetic field strength (H) squared, and power density (PD) values are shown in Table F.1. For near field exposures PD cannot be measured directly, but equivalent plane wave power density can be calculated from the field strength measurement data as follows:

$$\text{PD in mW/cm}^2 = E^2 / 3770$$

where: E^2 is in volts squared (V^2) per meter squared (m^2).

$$\text{PD in mW/cm}^2 = 37.7\ H^2$$

where: H^2 is in amperes squared (A^2) per meter squared (m^2).

These values should be used as guides in the evaluation and control of exposure to radio frequency/microwave radiation, and should not be regarded as a fine line between safe and dangerous levels.

NOTES:

1. Needless exposure to all radio frequency radiation (RFR) exposures should be avoided given the current state of knowledge on human effects, particularly nonthermal effects.
2. For fields consisting of a number of frequencies, the fraction of the protection guide incurred within each frequency level should be determined and the sum of all fractions should not exceed unity.
3. For pulsed and continuous wave fields, the power density is averaged over the six minute period.
4. For partial body exposures at frequencies between 10 kHz and 1.0 GHz, the protection guides in Table F.1 may be exceeded if the output power of a radiating device is seven watts or less. For example, if a hand held transmitter operating at 27 MHz has a maximum output of five watts, it would be excluded from any further field measurements.
5. The TLVs in Table F.1 may be exceeded if the exposure conditions can be demonstrated to produce a SAR of less than 0.4 W/kg as averaged over the whole body and spatial peak SAR values less than 8.0 W/kg as averaged over any 1.0 gram of tissue. For example, for frequencies from 3 to 30 MHz, the equivalent power density can be increased by a factor of ten up to a limit of 100 mW/cm^2, if it can be assured that exposed individuals are not in contact with the ground plate.
6. No measurement should be made within five cm of any object.
7. All exposures should be limited to a maximum (peak) electric field intensity of 100 kV/m.

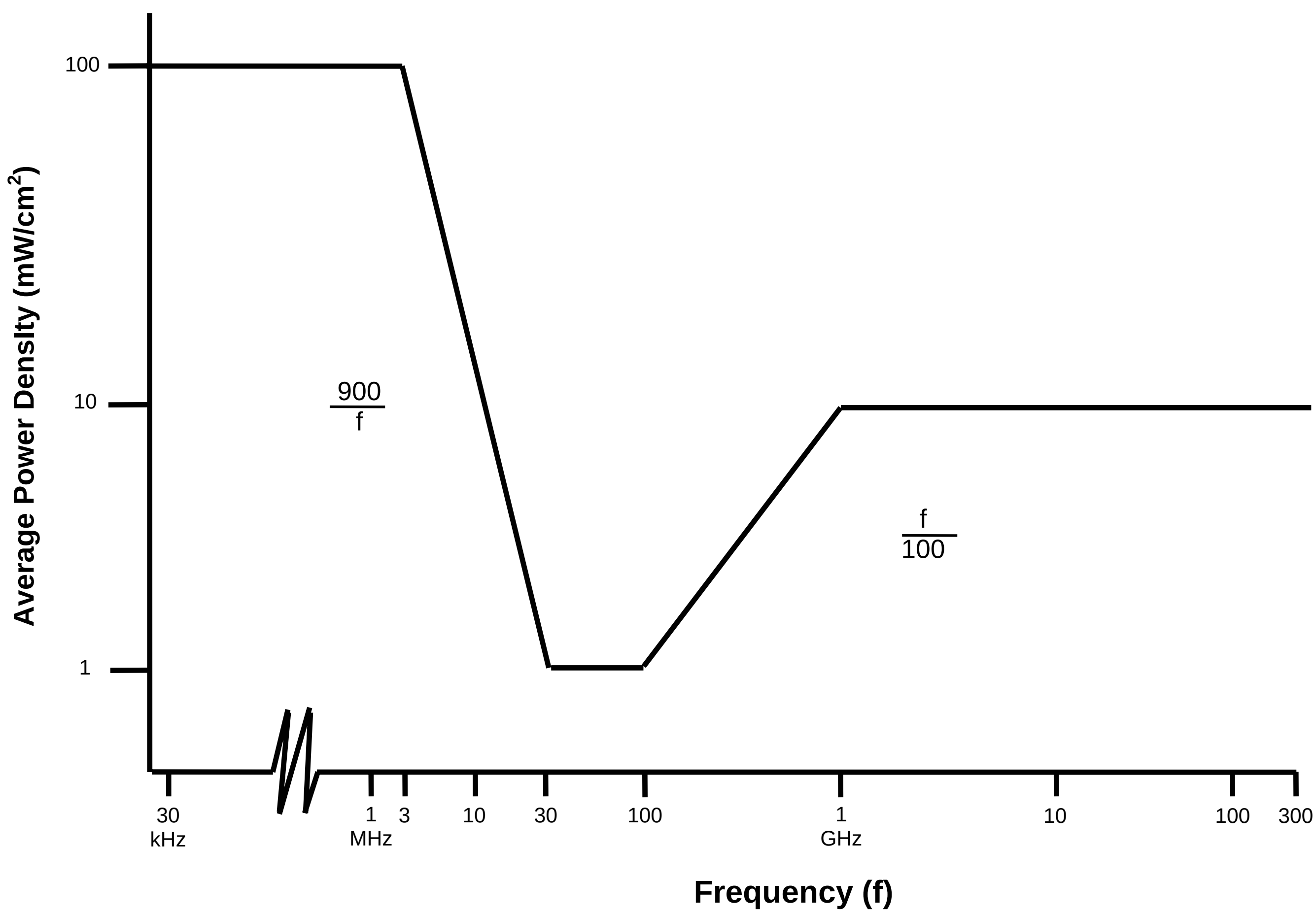

Figure F.1, Threshold Limit Values (TLVs) of Average Power Density for Radio Frequency/Microwave Radiation in the Workplace (whole body SAR less than 0.4 W/kg).

TABLE F.1, Radio Frequency/Microwave Threshold Limit Values.			
Frequency*	**Power Density (mW/cm^2)**	**Electric Field Strength Squared (V^2/m^2)**	**Magnetic Field Strength Squared (A^2/m^2)**
10 KHz to 3 MHz	100	377,000	2.65
3 MHz to 30 MHz	900/f*	3770 x 900/f	900/(37.7 x f)
30 MHz to 100 MHz	1	3770	0.027
100 MHz to 1000 Mhz (1 Ghz)	f/100	3770 f/100	f/(37.7 x 100)
1 GHz to 300 GHz	10	37,700	0.265

*f = frequency in Mhz.

D.2 RECOMMENDATIONS FOR STATIC MAGNETIC FIELDS STANDARDS

The ACGIH recommends that occupational exposure to static magnetic fields in the workplace be controlled by compliance with the "Exposure Standards" described below. Static magnetic fields are defined as those magnetic fields propagated from a magnetic source with frequencies at 30,000 Hertz and below. These criteria and the recommended standard will be reviewed and revised when relevant information warrants.

Exposure Standards - Sub-Radio Frequency (30 kHz and below) Magnetic Fields

These TLVs refer to the amplitude of the magnetic flux density (B) of sub radio frequency magnetic fields in the frequency range of 30 kHz and below to which it is believed that nearly all workers may be exposed repeatedly without adverse health effects. The magnetic field strengths in these TLVs are root mean square (rms) values. These values should be used as guides in the control of exposure to sub radio frequency magnetic fields and should not be regarded as a fine line between safe and dangerous levels.

Routine occupational exposure should not exceed:

$$B_{TLV_f} = 60 \text{ mT} / f \text{ (whole body)}$$

where: f is the frequency in Hz.

At frequencies at or below one Hz, the TLV is 60 mT (that is, 600 gauss).

Extremity exposure should not exceed 600 mT.

The permissible magnetic flux density of 60 mT/f (Hz) at 60 Hz corresponds to a maximum permissible flux density of one mT. At 30 kHz, the TLV is two μT which corresponds to a magnetic field strength of 1.6 A/m.

For workers wearing cardiac pacemakers, the TLV may not protect against electromagnetic interference with pacemaker function. The TLV for pacemaker wearers should be reduced by a safety factor of ten. For example, the magnetic flux density of 60 Hz would be 0.1 mT for pacemaker wearers.

D.3 RECOMMENDATIONS FOR STATIC ELECTRIC FIELDS STANDARD(S)

The ACGIH recommends that occupational exposure to static electric fields in the workplace be controlled by the “Exposure Standards” described below. Static electric fields are defined as those electric fields propagated from an electrical source with frequencies at 30,000 Hertz and below.

Exposure Standards - Sub Radio Frequency (30 kHz and below) and Static Electric Fields

These TLVs refer to the maximum unprotected workplace field strengths of sub radio frequency electric fields (30 kHz and below) and static electric fields that represent conditions under which it is believed that nearly all workers may be exposed repeatedly without adverse health effects. The electric field intensities in these TLVs are root mean square (rms) values. The values should be used as guides in the control of exposure and, due to individual susceptibility, should not be regarded as a fine line between safe and dangerous levels. The electric field strengths stated in this TLV refer to the field levels present in air, away from the surfaces of conductors (where spark discharges and contact currents may pose significant hazards).

Occupational exposures should not exceed a field strength of 25 kV/m from 0 Hz (DC) to 100 Hz. For frequencies in the range of 100 Hz to four kHz, the TLV is given by:

$E_{TLV} = 2.5 \times 106 / f$ in V/m

where: f is the frequency in Hz.

A value of 625 V/m is the exposure limit for frequencies from four kHz to 30 kHz.

NOTES:

1. This TLV is based on limiting currents on the body surface and induced internal currents to levels below those that are believed to produce adverse health effects. Certain biological effects have been demonstrated in laboratory studies at electric field strengths below those permitted in the TLV; however, there is no convincing evidence at the present time that occupational exposure to these field levels leads to adverse health effects.
2. Field strengths greater than approximately five to seven kV/m can produce a wide range of safety hazards such as startle reactions associated with spark discharges and contact currents from ungrounded conductors within the field. In addition, safety hazards associated with combustion, ignition of flammable materials and electro explosive devices may exist when a high intensity electric field

is present. Care should be taken to eliminate ungrounded objects, to ground such objects, or to use insulated gloves when ungrounded objects must be handled. Prudence dictates the use of protective devices (for example, suits, gloves, and insulation) in all fields exceeding 15 kV/m.

E. ACRONYMS

ACGIH	American Conference of Governmental Hygienists
ANSI	American National Standards Institute
CFR	Code of Federal Regulations
COTR	Contracting Officer's Technical Representative
cw	Continuous wavelength
DOT	Department of Transportation
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
OHR	Office of Human Resources
LAPD	Langley Policy Directive
LPR	Langley Procedural Requirements
LaRC	Langley Research Center
MPE	Maximum Permissible Exposure
NASA	National Aeronautics and Space Administration
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NIR	Nonionizing Radiation
NIRC	Nonionizing Radiation Committee
NRC	Nuclear Regulatory Commission
PR/PO	purchase request/purchase order
OFSH	Organizational Facility Safety Head
OHO	Occupational Health Officer
OHR	Office of Human Resources
LMT	Logistics Management Team, Center Operations Directorate
OMC	Occupational Medical Center
SMAO	Safety and Mission Assurance Office
SFAB	Safety and Facility Assurance Branch
OSHA	Occupational Safety and Health Administration
PFSH	Principal Facility Safety Head
rem	Roentgen equivalent man
RF	Radio Frequency
RFR	Radio Frequency Radiation
RSO	Radiation Safety Officer
SAR	Specific Absorption Rate
SDL	Standard Distribution List
TLV	Threshold Limit Value
UL	Underwriters Laboratories (Incorporated)
YAG	Yttrium Aluminum Garnet